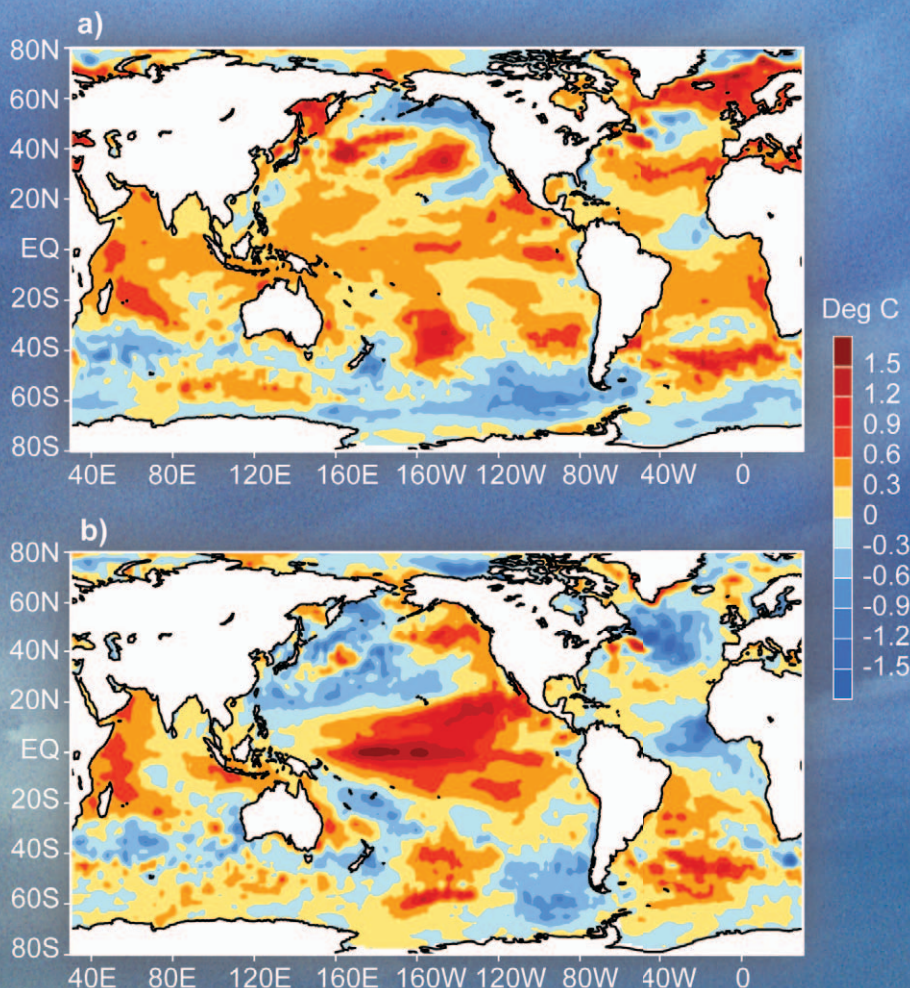


# STATE OF THE CLIMATE IN 2009

D.S. Arndt, M.O. Baringer and M.R. Johnson, Eds.

Associate Eds. L.V. Alexander, H.J. Diamond, R.L. Fogt, J.M. Levy,  
J. Richter-Menge, P.W. Thorne, L.A. Vincent, A.B. Watkins and K.M. Willett



(a) Yearly mean sea surface temperature anomalies (SSTA) in 2009 and (b) SSTA differences between 2009 and 2008. Anomalies are defined as departures from the 1971-2000 climatology. Refer to Chapter 3, Figure 3.1 for a more detailed description.

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# STATE OF THE CLIMATE IN 2009



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## EDITOR & AUTHOR AFFILIATIONS (ALPHABETICAL BY NAME)

### EDITORS

**Alexander, Lisa V.**, Climate Change Research Centre, University of New South Wales, Sydney, New South Wales, Australia  
**Arndt, Derek S.**, NOAA/NESDIS National Climatic Data Center, Asheville, North Carolina  
**Baringer, Molly O.**, NOAA/OAR Atlantic Oceanographic and Meteorological Laboratory, Physical Oceanography Division, Miami, Florida  
**Diamond, Howard J.**, NOAA/NESDIS National Climatic Data Center, Silver Spring, Maryland  
**Fogt, Ryan L.**, Department of Geography, Ohio University, Athens, Ohio  
**Johnson, Michael R.**, NOAA National Marine Fisheries Service, Gloucester, Massachusetts  
**Levy, Joel M.**, NOAA/OAR Climate Program Office, Silver Spring, Maryland  
**Richter-Menge, Jacqueline**, US Army Corps of Engineers, ERDC-Cold Regions Research and Engineering Laboratory, Hanover, New Hampshire  
**Thorne, Peter W.**, Met Office Hadley Centre, Exeter, Devon, United Kingdom  
**Vincent, Lucie A.**, Environment Canada, Toronto, Canada  
**Watkins, Andrew B.**, National Climate Centre, Australian Bureau of Meteorology, Melbourne, Australia  
**Willett, Katharine M.**, Met Office Hadley Centre, Exeter, Devon, United Kingdom

### AUTHORS

**Aceituno, Patricio**, Universidad de Chile, Santiago, Chile  
**Achberger, Christine**, Earth Sciences Centre, University of Gothenburg, Gothenburg, Sweden  
**Ackerman, Steven A.**, CIMSS University of Wisconsin - Madison, Madison, Wisconsin  
**Aguilar, Enrique**, University Rovira I Virgili de Tarragona, Tarragona, Spain  
**Ahmed, Farid H.**, Météo Nationale Comorienne, Comores  
**Alexander, Lisa V.**, Climate Change Research Centre, University of New South Wales, Sydney, New South Wales, Australia  
**Alfaro, Eric J.**, Center for Geophysical Research and School of Physics, University of Costa Rica, San Jose, Costa Rica  
**Allan, Robert J.**, Met Office Hadley Centre, Exeter, Devon, United Kingdom  
**Alves, Lincoln**, Centro de Ciências do Sistema Terrestre (CCST), Instituto Nacional de Pesquisas Espaciais (INPE), São Paulo, Brazil  
**Amador, Jorge A.**, Center for Geophysical Research and School of Physics, University of Costa Rica, San Jose, Costa Rica  
**Ambenje, Peter**, Kenya Meteorological Department, Nairobi, Kenya  
**Amelie, Vincent**, Seychelles Meteorological Services, Seychelles  
**Antonov, John I.**, NOAA/NESDIS National Ocean Data Center, Silver Spring, Maryland  
**Ashik, Igor**, Arctic and Antarctic Research Institute, St. Petersburg, Russia  
**Atheru, Zachary**, IGAD Climate Prediction and Applications Centre, Nairobi, Kenya

**Attaher, Samar M.**, Agricultural Research Center, MALR, Cairo, Egypt  
**Baez, Julian**, DMH-DINAC / CTA-UCA, Asunción, Paraguay  
**Banda, Joyce**, Zimbabwe Meteorological Service, Zimbabwe  
**Banzon, Viva**, NOAA/NESDIS National Climatic Data Center, Asheville, North Carolina  
**Baringer, Molly O.**, NOAA/OAR Atlantic Oceanographic and Meteorological Laboratory, Physical Oceanography Division, Miami, Florida  
**Barreira, Sandra**, Argentine Naval Hydrographic Service, Buenos Aires, Argentina  
**Barriopedro, David**, Centro de Geofísica da Universidade de Lisboa, Lisbon, Portugal  
**Beal, Lisa M.**, Rosenstiel School of Marine and Atmospheric Science, Division of Meteorology and Physical Oceanography, Miami, Florida  
**Behrenfeld, Michael J.**, Oregon State University, Corvallis, Oregon  
**Bell, Gerald D.**, NOAA/NWS/NCEP Climate Prediction Center, Camp Springs, Maryland  
**Belward, Alan S.**, Global Environment Monitoring Unit, IES, EC Joint Research Centre, Ispra, Italy  
**Benedetti, Angela**, European Centre for Medium-Range Weather Forecasts (ECMWF), Reading, United Kingdom  
**Beszczyńska-Moeller, Agnieszka**, Alfred Wegener Institute, Germany  
**Bhatt, Uma S.**, Geophysical Institute, University of Alaska Fairbanks, Fairbanks, Alaska  
**Bhattacharya, Indrajit**, Byrd Polar Research Center and Department of Geography, The Ohio State University, Columbus, Ohio  
**Bidegain, Mario**, Universidad de la República, Uruguay  
**Birkett, Charon**, ESSIC, University of Maryland, College Park, Maryland  
**Bissolli, Peter**, Deutscher Wetterdienst (German Meteorological Service, DWD), WMO RA VI Regional Climate Centre on Climate Monitoring, Offenbach, Germany  
**Blake, Eric S.**, NOAA/NWS/NCEP National Hurricane Center, Miami, Florida  
**Blunden, Jessica**, STG, Inc., Asheville, North Carolina  
**Booneeady, Prithiviraj**, Mauritius Meteorological Services, Vacoas, Mauritius  
**Bowling, Laura C.**, Department of Agronomy, Purdue University, West Lafayette, Indiana  
**Box, Jason E.**, Byrd Polar Research Center and Department of Geography, The Ohio State University, Columbus, Ohio  
**Boyer, Timothy P.**, NOAA/NESDIS National Ocean Data Center, Silver Spring, Maryland  
**Bromwich, David H.**, Byrd Polar Research Center, The Ohio State University, Columbus, Ohio  
**Brown, Ross**, Climate Research Division, Environment Canada, Montréal, Quebec, Canada  
**Bryden, Harry L.**, Ocean Observing and Climate Research Group, National Oceanography Centre, Southampton, United Kingdom

- Bulygina, Olga N.**, All-Russian Research Institute of Hydro-meteorological Information – World Data Center, Obninsk, Russia
- Calderon, Blanca**, Center for Geophysical Research, University of Costa Rica, San Jose, Costa Rica
- Camargo, Suzana J.**, Lamont-Doherty Earth Observatory, The Earth Institute at Columbia University, Palisades, New York
- Cappelen, John**, Danish Meteorological Institute, Copenhagen, Denmark
- Carmack, Eddy**, Institute of Ocean Sciences, Sidney, Canada
- Carrasco, Gualberto**, Servicio Nacional de Meteorología e Hidrología de Bolivia (SENAMHI), La Paz, Bolivia
- Carrión Romero, Ana M.**, Institute of Meteorology of Cuba, La Habana, Cuba
- Christy, John R.**, Earth System Science Center, University of Alabama in Huntsville, Huntsville, Alabama
- Coelho, Caio A. S.**, CPTEC/INPE, Center for Weather Forecasts and Climate Studies, Cachoeira Paulista, Brazil
- Colwell, Steve**, British Antarctic Survey, Cambridge, United Kingdom
- Comiso, Josefino C.**, NASA Goddard Space Flight Center, Greenbelt, Maryland
- Crouch, Jake**, NOAA/NESDIS National Climatic Data Center, Asheville, North Carolina
- Cunningham, Stuart A.**, Ocean Observing and Climate Research Group, National Oceanography Centre, Southampton, United Kingdom
- Cutié Cancino, Virgen**, Institute of Meteorology of Cuba, La Habana, Cuba
- Davydova-Belitskaya, Valentina**, National Meteorological Service of Mexico, Mexico City, Mexico
- Decker, David**, Byrd Polar Research Center and Department of Geography, The Ohio State University, Columbus, Ohio
- Derksen, Chris**, Climate Research Division, Environment Canada, Downsview, Ontario, Canada
- Diamond, Howard J.**, NOAA/NESDIS National Climatic Data Center, Silver Spring, Maryland
- Dlugokencky, Ed J.**, NOAA Global Monitoring Division, Earth System Research Laboratory, Boulder, Colorado
- Doelling, David R.**, NASA Langley Research Center, Hampton, Virginia
- Dohan, Kathleen**, Earth and Space Research, Seattle, Washington
- Drozhdov, Dmitry S.**, Earth Cryosphere Institute, Tumen, Russia
- Dutton, Geoffrey S.**, NOAA Earth Science Research Laboratory/Cooperative Institute for Research in Environmental Sciences (CIRES), Boulder, Colorado
- Elkins, James W.**, NOAA Earth Science Research Laboratory, Boulder, Colorado
- Epstein, Howard E.**, Department of Environmental Sciences, University of Virginia, Charlottesville, Virginia
- Feely, Richard A.**, NOAA/OAR Pacific Marine Environmental Laboratory, Seattle, Washington
- Fekete, Balázs M.**, NOAA CREST Center, The City College of New York, New York, New York
- Fenimore, Chris**, NOAA/NESDIS National Climatic Data Center, Asheville, North Carolina
- Fettweis, Xavier**, Department of Geography, University of Liège, Belgium
- Fogt, Ryan L.**, Department of Geography, Ohio University, Athens, Ohio
- Fonseca-Rivera, Cecilia**, Institute of Meteorology of Cuba, La Habana, Cuba
- Foster, Michael J.**, AOS/CIMSS University of Wisconsin—Madison, Madison, Wisconsin
- Free, Melissa**, NOAA Air Resources Laboratory, Silver Spring, Maryland
- Frolov, Ivan**, Arctic and Antarctic Research Institute, St. Petersburg, Russia
- Gibney, Ethan J.**, IMSG Inc., Asheville, North Carolina
- Gill, Stephen**, NOAA/NOS Center for Operational Oceanographic Products and Services, Silver Spring, Maryland
- Gitau, Wilson**, Department of Meteorology, University of Nairobi, Kenya
- Gleason, Karin L.**, NOAA/NESDIS National Climatic Data Center, Asheville, North Carolina
- Gobron, Nadine**, Global Environment Monitoring Unit, IES, EC Joint Research Centre, Ispra, Italy
- Goldammer, Johann G.**, Global Fire Monitoring Centre, Max Planck Institute for Chemistry, Freiburg University / United Nations University (UNU), Germany and European Centre for Medium-Range Weather Forecasts (ECMWF), Reading, United Kingdom
- Goldenberg, Stanley B.**, NOAA/OAR Atlantic Oceanographic and Meteorological Laboratory, Miami, Florida
- Goni, Gustavo**, NOAA/OAR Atlantic Oceanographic and Meteorological Laboratory, Physical Oceanography Division, Miami, Florida
- González García, Idelmis**, Institute of Meteorology of Cuba, La Habana, Cuba
- Good, Simon A.**, Met Office Hadley Centre, Exeter, Devon, United Kingdom
- Gottschalck, Jonathan**, NOAA/NWS/NCEP Climate Prediction Center, Camp Springs, Maryland
- Gould, William A.**, USDA Forest Service, International Institute of Tropical Forestry, San Juan, Puerto Rico
- Gouveia, Celia M.**, Centro de Geofísica da Universidade de Lisboa, Lisbon, Portugal
- Griffiths, Georgina**, National Institute of Water & Atmospheric Research Ltd., Auckland, New Zealand
- Guard, Charles P.**, NOAA National Weather Service Forecast Office, Barrigada, Guam
- Haimberger, Leopold**, University of Vienna, Vienna, Austria
- Haines, Keith**, Reading University, Reading, United Kingdom
- Halpert, Michael S.**, NOAA/NWS/NCEP Climate Prediction Center, Camp Springs, Maryland
- Hassane, Ahmed Farid**, Météo Nationale Comorienne, Comores
- Heidinger, Andrew K.**, NOAA/NESDIS University of Wisconsin—Madison, Madison, Wisconsin

- Heim, Richard R., Jr.**, NOAA/NESDIS National Climatic Data Center, Asheville, North Carolina
- Henry, Greg H.R.**, Geography Department, University of British Columbia, Vancouver, British Columbia, Canada
- Hidalgo, Hugo G.**, Center for Geophysical Research and School of Physics, University of Costa Rica, San Jose, Costa Rica
- Hilburn, Kyle A.**, Remote Sensing Systems, Santa Rosa, California
- Hirschi, Joël J.M.**, Ocean Observing and Climate Research Group, National Oceanography Centre, Southampton, United Kingdom
- Ho, Shu-peng B.**, NCAR COSMIC, Boulder, Colorado
- Hoerling, Martin P.**, NOAA/NESDIS Earth System Research Laboratory, Boulder, Colorado
- Jaimes, Ena**, Servicio Nacional de Meteorología e Hidrología de Perú, Lima, Perú
- Jezek, Kenneth C.**, Byrd Polar Research Center, The Ohio State University, Columbus, Ohio
- Jia, Gensu J.**, RCE-TEA, CAS, Chinese Academy of Sciences, Institute for Atmospheric Physics, Beijing, China
- Johns, William E.**, Rosenstiel School of Marine and Atmospheric Science, Division of Meteorology and Physical Oceanography, Miami, Florida
- Johnson, Bryan**, NOAA Earth System Research Laboratory, Global Monitoring Division, and University of Colorado, Boulder, Colorado
- Johnson, Gregory C.**, NOAA/OAR Pacific Marine Environmental Laboratory, Seattle, Washington
- Jumaux, Guillaume**, Météo-France, Réunion
- Kabidi, Khadija**, Direction de la Météorologie Nationale, Rabat, Morocco
- Kaiser, Johannes W.**, European Centre for Medium-Range Weather Forecasts (ECMWF), Reading, United Kingdom
- Kanzow, Torsten O.**, Ocean Observing and Climate Research Group, National Oceanography Centre, Southampton, United Kingdom
- Keller, Linda M.**, Department of Atmospheric and Oceanic Sciences, University of Wisconsin—Madison, Madison, Wisconsin
- Kennedy, John J.**, Met Office Hadley Centre, Exeter, Devon, United Kingdom
- Khatiwala, Samar**, Lamont-Doherty Earth Observatory, Columbia University, Palisades, New York
- Kholodov, Alexander L.**, Geophysical Institute, University of Alaska Fairbanks, Fairbanks, Alaska
- Khoskam, Mahbobeh**, Islamic Republic of Iran Meteorological Organization, Tehran, Iran
- Kimberlain, Todd B.**, NOAA/NWS/NCEP National Hurricane Center, Miami, Florida
- Knaff, John A.**, NOAA/NESDIS Center for Satellite Applications and Research, Fort Collins, Colorado
- Knorr, Wolfgang**, Department of Earth Science, University of Bristol, Bristol, United Kingdom
- Kokelj, Steve V.**, Water Resources Division, Indian and Northern Affairs Canada, Yellowknife, Northwest Territories, Canada
- Korshunova, Natalia N.**, All-Russian Research Institute of Hydrometeorological Information – World Data Center, Obninsk, Russia
- Kratz, David P.**, NASA Langley Research Center, Hampton, Virginia
- Krishfield, Richard**, Woods Hole Oceanographic Institution, Woods Hole, Massachusetts
- Kruger, Andries**, South African Weather Service, South Africa
- Kruk, Michael C.**, STG Inc., Asheville, North Carolina
- Kuo, Ying-Hwa**, NCAR COSMIC, Boulder, Colorado
- Kwok, Ron**, Jet Propulsion Laboratory, Pasadena, California
- L'Heureux, Michelle**, NOAA/NWS/NCEP Climate Prediction Center, Camp Springs, Maryland
- Lammers, Richard B.**, WSAG/CSRC Institute for the Study of Earth, Oceans, and Space, University of New Hampshire, Durham, New Hampshire
- Lander, Mark A.**, Water and Environmental Research Institute, University of Guam, Mangilao, Guam
- Landsea, Chris W.**, NOAA/NWS/NCEP National Hurricane Center, Miami, Florida
- Lantz, Trevor C.**, School of Environmental Studies, University of Victoria, Victoria, British Columbia, Canada
- Lapinel Pedroso, Braulio**, Institute of Meteorology of Cuba, La Habana, Cuba
- Lawford, Richard**, Hydrological and Biospheric Sciences, NASA GSFC, Greenbelt, Maryland
- Lawrimore, Jay H.**, NOAA/NESDIS National Climatic Data Center, Asheville, North Carolina
- Lazzara, Matthew A.**, Space Science and Engineering Center, University of Wisconsin—Madison, Madison, Wisconsin
- León, Gloria**, Instituto de Hidrología de Meteorología y Estudios Ambientales de Colombia (IDEAM), Bogotá, Colombia
- León Lee, Antonia**, Institute of Meteorology of Cuba, La Habana, Cuba
- Leuliette, Eric**, NOAA/NESDIS Laboratory for Satellite Altimetry, Silver Spring, Maryland
- Levinson, David H.**, NOAA/NESDIS National Climatic Data Center, Asheville, North Carolina
- Levitus, Sydney**, NOAA/NESDIS National Ocean Data Center, Silver Spring, Maryland
- Levy, Joel M.**, NOAA/OAR Climate Program Office, Silver Spring, Maryland
- Lin, I.-I.**, Department of Atmospheric Sciences, National Taiwan University, Taipei, Taiwan
- Liu, Hongxing**, Department of Geography, University of Cincinnati, Cincinnati, Ohio
- Loeb, Norman G.**, NASA Langley Research Center, Hampton, Virginia
- Long, Craig S.**, NOAA National Center for Environmental Prediction, Camp Springs, Maryland
- Lorrey, Andrew M.**, National Institute of Water and Atmospheric Research, Ltd., Auckland, New Zealand
- Lumpkin, Rick**, NOAA/OAR Atlantic Oceanographic and Meteorological Laboratory, Physical Oceanography Division, Miami, Florida

- Luo, Jing-Jia**, Research Institute for Global Change, JAMSTEC, Yokohama, Japan
- Lyman, John M.**, NOAA/OAR Pacific Marine Environmental Laboratory, Seattle, Washington and Joint Institute for Marine and Atmospheric Research, University of Hawaii, Honolulu, Hawaii
- Macdonald, Alison M.**, Woods Hole Oceanographic Institution, Woods Hole, Massachusetts
- Maddux, Brent C.**, AOS/CIMSS University of Wisconsin—Madison, Madison, Wisconsin
- Malkova, Galina**, Earth Cryosphere Institute, Tumen, Russia
- Marchenko, Sergey S.**, Geophysical Institute, University of Alaska Fairbanks, Fairbanks, Alaska
- Marengo, Jose A.**, Centro de Ciências do Sistema Terrestre (CCST), Instituto Nacional de Pesquisas Espaciais (INPE), São Paulo, Brazil
- Maritorena, Stephane**, University of California at Santa Barbara, Santa Barbara, California
- Marotzke, Jochem**, Max-Planck-Institut für Meteorologie, Hamburg, Germany
- Martínez, Rodney**, Centro Internacional para la Investigación del Fenómeno El Niño (CIIFEN), Guayaquil, Ecuador
- Mascarenhas, Affonso**, Centro Internacional para la Investigación del Fenómeno El Niño (CIIFEN), Guayaquil, Ecuador
- Massom, Robert A.**, Australian Antarctic Division and Antarctic Climate and Ecosystems Cooperative Research Center (ACE CRC), University of Tasmania, Sandy Bay, Tasmania, Australia
- McBride, Charlotte**, South African Weather Service, Pretoria, South Africa
- McGree, Simon**, National Climate Centre, Australian Bureau of Meteorology, Melbourne, Victoria, Australia
- McLaughlin, Fiona**, Institute of Ocean Sciences, Sidney, Canada
- Mears, Carl A.**, Remote Sensing Systems, Santa Rosa, California
- Medany, Mahmoud A.**, Agricultural Research Center, MALR, Cairo, Egypt
- Meier, Walt**, CIRES/NSIDC, University of Colorado, Boulder, Colorado
- Meinen, Christopher S.**, NOAA/OAR Atlantic Oceanographic and Meteorological Laboratory, Physical Oceanography Division, Miami, Florida
- Menne, Matthew J.**, NOAA/NESDIS National Climatic Data Center, Asheville, North Carolina
- Mercado-Díaz, Joel A.**, USDA Forest Service, International Institute of Tropical Forestry, San Juan, Puerto Rico
- Merrifield, Mark A.**, University of Hawaii at Manoa, Honolulu, Hawaii
- Mhanda, Albert S.**, Climate Change Office, Harare, Zimbabwe
- Miller, Laury**, NOAA/NESDIS Laboratory for Satellite Altimetry, Silver Spring, Maryland
- Mitchum, Gary T.**, College of Marine Science, University of South Florida, St. Petersburg, Florida
- Montfraix, Brice**, Commission de l'Océan Indien (Projet AC-CLIMATE), Quatre-Bornes, Maurice
- Montzka, Steve A.**, NOAA Global Monitoring Division, Earth System Research Laboratory, Boulder, Colorado
- Morcrette, Jean-Jacques**, European Centre for Medium-Range Weather Forecasts (ECMWF), Reading, United Kingdom
- Morison, James**, Polar Science Center, University of Washington, Seattle, Washington
- Mote, Thomas**, Department of Geography, University of Georgia, Athens, Georgia
- Mullan, A. Brett**, National Institute of Water and Atmospheric Research, Ltd., Wellington, New Zealand
- Na, Hyun-Jong**, Climate Prediction Division, Korea Meteorological Administration, Seoul, Korea
- Nash, Eric R.**, Science Systems and Applications, Inc., NASA Goddard Space Flight Center, Greenbelt, Maryland
- Nerem, Steven R.**, University of Colorado, Boulder, Colorado
- Newman, Paul A.**, Laboratory for Atmospheres, NASA Goddard Space Flight Center, Greenbelt, Maryland
- Nghiem, Son**, Jet Propulsion Laboratory, Pasadena, California
- Nguyen, Louis C.**, NASA Langley Research Center, Hampton, Virginia
- Njau, Leonard**, African Centre of Meteorological Applications for Development (ACMAD), Niamey, Niger
- O'Malley, Robert T.**, Oregon State University, Corvallis, Oregon
- Oberman, Naum G.**, MIREKO, Syktivkar, Russia
- Obregón, Andre**, Laboratory for Climatology and Remote Sensing (LCRS), Department of Geography, University of Marburg, Marburg, Germany
- Ogallo, Laban**, IGAD Climate Prediction and Applications Centre, Nairobi, Kenya
- Oludhe, Christopher**, Department of Meteorology, University of Nairobi, Nairobi, Kenya
- Osawa, Kazuhiro**, Climate Prediction Division, Japan Meteorological Agency, Tokyo, Japan
- Overland, James**, NOAA Pacific Marine Environmental Laboratory, Seattle, Washington
- Palmer, Matthew D.**, Met Office Hadley Centre, Exeter, Devon, United Kingdom
- Park, Geun-Ha**, NOAA/OAR Atlantic Oceanographic and Meteorological Laboratory, Ocean Chemistry Division, Miami, Florida
- Parker, David E.**, Met Office, FitzRoy Road, Exeter, Devon, United Kingdom
- Pasch, Richard J.**, NOAA/NWS/NCEP National Hurricane Center, Miami, Florida
- Peltier, Alexandre**, Météo-France, New Caledonia, Wallis and Futuna Service, Climatology Division, Noumea
- Pelto, Mauri S.**, Nichols College, Dudley, Massachusetts
- Penalba, Olga**, Departamento de Ciencias de la Atmósfera y los Océanos, Universidad de Buenos Aires, Argentina
- Pérez-Suarez, Ramón**, Institute of Meteorology of Cuba, La Habana, Cuba
- Perovich, Donald**, ERDC-Cold Regions Research and Engineering Laboratory, Hanover, New Hampshire
- Peterson, Thomas C.**, NOAA/NESDIS National Climatic Data Center, Asheville, North Carolina
- Pezza, Alexandre B.**, The University of Melbourne, Melbourne, Victoria, Australia

- Phillips, David**, Environment Canada, Toronto, Canada
- Pinty, Bernard**, Monitoring Unit, IES, EC Joint Research Centre, Ispra, Italy (Seconded to the Earth Observation Directorate, ESA-ESRIN, Frascati, Italy)
- Pinzon, Jorge E.**, NASA Goddard Space Flight Center, Greenbelt, Maryland
- Pitts, Michael C.**, NASA Langley Research Center, Hampton, Virginia
- Polyakov, Igor**, International Arctic Research Center, Fairbanks, Alaska
- Proshutinsky, Andrey**, Woods Hole Oceanographic Institution, Woods Hole, Massachusetts
- Quintana, Juan**, Dirección Meteorológica de Chile, Santiago, Chile
- Quintero, Alexander**, Servicio de Meteorología de l'Aviación (SEMETAVIA), Maracay, Aragua, Venezuela
- Rachid, Sebbari**, Direction de la Météorologie Nationale, Rabat, Morocco
- Rahimzadeh, Fatemeh**, Atmospheric Science and Meteorological Research Center, Tehran, Iran
- Rajeevan, Madhavan**, National Atmospheric Research Laboratory, Tirupati, India
- Randel, William**, Atmospheric Chemistry Division, NCAR, Boulder, Colorado
- Randriamarolaza, Luc Y.A.**, Service Météorologique de Madagascar, Madagascar
- Rayner, Darren**, Ocean Observing and Climate Research Group, National Oceanography Centre, Southampton, United Kingdom
- Raynolds, Martha K.**, Institute of Arctic Biology, University of Alaska Fairbanks, Fairbanks, Alaska
- Razuvaev, Vyacheslav N.**, All-Russian Research Institute of Hydrological Information, Obninsk, Russia
- Reid, Phillip**, Australian Bureau of Meteorology and ACE CRC, University of Tasmania, Sandy Bay, Tasmania, Australia
- Renwick, James**, National Institute of Water and Atmospheric Research, Ltd., Wellington, New Zealand
- Revadekar, Jayashree**, Indian Institute of Tropical Meteorology, Pune, India
- Reynolds, Richard W.**, NOAA Cooperative Institute for Climate and Satellites, Asheville, North Carolina
- Richter-Menge, Jacqueline**, US Army Corps of Engineers, ERDC-Cold Regions Research and Engineering Laboratory, Hanover, New Hampshire
- Rivera, Erick R.**, Center for Geophysical Research, University of Costa Rica, San Jose, Costa Rica
- Robinson, David A.**, Rutgers University, Piscataway, New Jersey
- Rogers, Mark**, Joint Operational Meteorology and Oceanography Centre, Met Office, Exeter, United Kingdom
- Romanovsky, Vladimir**, Geophysical Institute, University of Alaska Fairbanks, Fairbanks, Alaska
- Romero-Cruz, Fernando**, National Meteorological Service of Mexico, Mexico City, Mexico
- Ronchail, Josyane**, Université de Paris, Paris, France
- Rossi, Shawn**, National Weather Service, San Juan, Puerto Rico
- Ruedy, Reto A.**, Sigma Space Partners LLC, NASA Goddard Institute for Space Studies, New York, New York
- Sabine, Christopher L.**, NOAA/OAR Pacific Marine Environmental Laboratory, Seattle, Washington
- Saindou, Madjidi**, Météo National Comorienne, Comores
- Santee, Michelle L.**, NASA Jet Propulsion Laboratory, Pasadena, California
- Sayouri, Amal**, Direction de la Météorologie Nationale, Rabat, Morocco
- Schemm, Jae**, NOAA/NWS/NCEP Climate Prediction Center, Camp Springs, Maryland
- Schnell, Russ C.**, NOAA Global Monitoring Division, Earth System Research Laboratory, Boulder, Colorado
- Schreiner, William**, NCAR COSMIC, Boulder, Colorado
- Schueller, Dominique**, Météo-France, Réunion
- Sensoy, Serhat**, Turkish State Meteorological Service, Kalaba, Ankara, Turkey
- Sharp, Martin**, University of Alberta, Department of Earth and Atmospheric Sciences, Edmonton, Alberta, Canada
- Shaver, Gus R.**, Ecosystem Center, Marine Biological Laboratory, Woods Hole, Massachusetts
- Shiklomanov, Alexander**, University of New Hampshire, Durham, New Hampshire
- Shimada, Koji**, Institute of Observational Research for Global Change, Japan Agency for Marine-Earth Science and Technology, Yokosuka, Japan
- Siegel, David A.**, University of California at Santa Barbara, Santa Barbara, California
- Skansi, Maria**, Servicio Meteorológico Nacional, Argentina
- Sokolov, Vladimir**, Arctic and Antarctic Research Institute, St. Petersburg, Russia
- Solonomenjanahary, Andrianjafinirina**, Service Météorologique de Madagascar, Madagascar
- Spence, Jacqueline M.**, Meteorological Service of Jamaica, Kingston, Jamaica
- Srivastava, Arvind Kumar**, National Climate Centre, India Meteorological Department, Pune, India
- Stackhouse, Paul W., Jr.**, NASA Langley Research Center, Hampton, Virginia
- Stammerjohn, Sharon**, University of California Santa Cruz, Santa Cruz, California
- Steele, Mike**, Polar Science Center, University of Washington, Seattle, Washington
- Steinbrecht, Wolfgang**, Met. Obs. Hohenpeissenberg, German Weather Service (DWD), Hohenpeissenberg, Germany
- Stephenson, Tannecia S.**, University of the West Indies, Mona, Jamaica
- Stott, Peter A.**, Met Office Hadley Centre, Exeter, Devon, United Kingdom
- Tahani, Lloyd**, Solomon Islands Meteorological Service, Honiara, Solomon Islands
- Takahashi, Taro**, Lamont-Doherty Earth Observatory, Columbia University, Palisades, New York
- Taylor, Michael A.**, University of the West Indies, Mona, Jamaica



**Tedesco, Marco**, Department Earth and Atmospheric Sciences, City College of New York, New York

**Thiaw, Wassila M.**, NOAA/NWS/NCEP Climate Prediction Center, Camp Springs, Maryland

**Thorne, Peter W.**, Met Office Hadley Centre, Exeter, Devon, United Kingdom

**Timmermans, Mary-Louise**, Yale University, New Haven, Connecticut

**Titchner, Holly A.**, Met Office Hadley Centre, Exeter, Devon, United Kingdom

**Toole, John**, Woods Hole Oceanographic Institution, Woods Hole, Massachusetts

**Trewin, Blair C.**, National Climate Centre, Australian Bureau of Meteorology, Melbourne, Victoria, Australia

**Trigo, Ricardo M.**, Centro de Geofísica da Universidade de Lisboa, Lisbon, Portugal

**Tucker, Compton J.**, NASA Goddard Space Flight Center, Greenbelt, Maryland

**Tweedie, Craig E.**, Department of Biology, The University of Texas at El Paso, El Paso, Texas

**Vincent, Lucie A.**, Environment Canada, Toronto, Canada

**Virasami, Renganaden**, Mauritius Meteorological Services, Vacoas, Mauritius

**Walker, David A.**, Institute of Arctic Biology, University of Alaska Fairbanks, Fairbanks, Alaska

**Walsh, John**, International Arctic Research Center, Fairbanks, Alaska

**Wang, Junhong**, Earth Observation Laboratory, NCAR, Boulder, Colorado

**Wang, Lei**, Department of Geography and Anthropology, Louisiana State University, Baton Rouge, Louisiana

**Wang, Libo**, Climate Research Division, Environment Canada, Downsview, Ontario, Canada

**Wang, Muyin**, Joint Institute for the Study of the Atmosphere and Ocean, University of Washington, Seattle, Washington

**Wang, Sheng-Hung**, Byrd Polar Research Center, The Ohio State University, Columbus, Ohio

**Wanninkhof, Rik**, NOAA/OAR Atlantic Oceanographic and Meteorological Laboratory, Ocean Chemistry Division, Miami, Florida

**Watkins, Andrew B.**, National Climate Centre, Australian Bureau of Meteorology, Melbourne, Australia

**Webber, Patrick J.**, Department of Plant Biology, Michigan State University, East Lansing, Michigan

**Weber, Mark**, Institute of Environmental Physics, University of Bremen, Bremen, Germany

**Weller, Robert A.**, Woods Hole Oceanographic Institution, Woods Hole, Massachusetts

**Weyman, James**, NOAA/NWS Central Pacific Hurricane Center, Honolulu, Hawaii

**Whitewood, Robert**, Environment Canada, Toronto, Canada

**Wilber, Anne C.**, Science Systems Applications, Inc., Hampton, Virginia

**Willett, Katharine M.**, Met Office Hadley Centre, Exeter, Devon, United Kingdom

**Willis, Joshua K.**, NASA Jet Propulsion Laboratory, California Institute of Technology, Pasadena, California

**Wolken, Gabriel**, Alaska Division of Geological & Geophysical Surveys, Fairbanks, Alaska

**Wong, Takmeng**, NASA Langley Research Center, Hampton, Virginia

**Woodgate, Rebecca**, Polar Science Center, University of Washington, Seattle, Washington

**Woodworth, Philip L.**, Proudman Oceanographic Laboratory, Liverpool, United Kingdom

**Xue, Yan**, NOAA/NWS Climate Prediction Center, National Centers for Environmental Prediction, Camp Springs, Maryland

**Yu, Lisan**, Woods Hole Oceanographic Institution, Woods Hole, Massachusetts

**Zhang, Liangying**, Earth Observation Laboratory, National Center for Atmospheric Research, Boulder, Colorado

**Zhang, Peiqun**, National Climate Centre, China Meteorological Administration, Beijing, China

**Zhou, Xinjia**, NCAR COSMIC, Boulder, Colorado

**Zhu, YanFeng**, National Climate Centre, China Meteorological Administration, Beijing, China

# TABLE OF CONTENTS

List of authors and affiliations .....	2
Abstract .....	12
<b>I. INTRODUCTION</b> .....	14
<b>2. GLOBAL CLIMATE</b> .....	19
a. Summary .....	19
b. Temperatures .....	19
1. Introduction of reanalysis data .....	19
2. Global surface temperatures .....	24
3. Lower tropospheric temperatures .....	25
4. Stratospheric temperatures .....	28
c. Hydrologic cycle .....	29
1. Total column water vapor .....	29
2. Global precipitation .....	31
3. Northern Hemisphere continental snow cover extent .....	32
4. Global cloudiness .....	34
5. River discharge .....	35
6. Lake levels .....	38
d. Atmospheric circulation .....	39
1. Mean sea level pressure .....	39
2. Surface wind speed .....	39
e. Earth radiation budget at top-of-atmosphere .....	41
f. Atmospheric composition .....	41
1. Atmospheric chemical composition .....	41
A. Carbon dioxide (CO <sub>2</sub> ) .....	41
B. Methane (CH <sub>4</sub> ) .....	42
C. Carbon monoxide (CO) .....	43
2. Global aerosols .....	45
3. Stratospheric ozone .....	46
g. Land surface properties .....	49
1. Alpine glaciers and ice sheets .....	49
2. Fraction of Absorbed Photosynthetically Active Radiation (FAPAR) .....	50
3. Biomass burning .....	51
<b>3. GLOBAL OCEANS</b> .....	53
a. Overview .....	53
b. Sea surface temperatures .....	53
c. Ocean heat content .....	56
d. Global ocean heat fluxes .....	59
e. Sea surface salinity .....	63
f. Surface currents .....	65
1. Pacific Ocean .....	65
2. Indian Ocean .....	66
3. Atlantic Ocean .....	66
g. The meridional overturning circulation .....	66
h. Sea level variations .....	69
i. The global ocean carbon cycle .....	71
1. Carbon dioxide fluxes .....	71
2. Subsurface carbon inventory .....	73
j. Global ocean phytoplankton .....	75

<b>4. THE TROPICS</b>	79
a. Overview	79
b. El Niño/Southern Oscillation (ENSO) and the tropical Pacific	79
1. Ocean conditions	79
2. Atmospheric circulation	80
3. ENSO temperature and precipitation impacts	82
c. Tropical intraseasonal activity	82
d. Tropical cyclones	84
1. Overview	84
2. Atlantic basin	84
3. Eastern North Pacific (ENP) basin	88
4. Western North Pacific (WNP) basin	91
5. Indian Ocean basins	95
6. Southwest Pacific basin	97
7. Australian region basin	98
e. TC Heat Potential (TCHP)	99
f. Intertropical Convergence Zones (ITCZ)	100
1. Pacific	100
2. Atlantic	102
g. Indian Ocean Dipole (IOD)	103
 <b>5. THE ARCTIC</b>	 107
a. Overview	107
b. Atmosphere	107
c. Ocean	109
1. Circulation	109
2. Water temperature and salinity	110
3. Sea level	112
d. Sea Ice Cover	113
1. Sea ice extent	113
2. Sea ice age and thickness	113
e. Land	115
1. Vegetation	115
2. Permafrost	116
3. River discharge	116
4. Terrestrial snow	117
5. Glaciers outside Greenland	119
f. Greenland	121
1. Coastal surface air temperatures	121
2. Upper-air temperatures	121
3. Atmospheric circulation anomalies	122
4. Surface melt extent and duration	122
5. Precipitation and surface mass balance	123
6. North water polynya	123
7. Outlet glaciers	124
 <b>6. ANTARCTICA</b>	 125
a. Overview	125
b. Atmospheric circulation	127

c. Surface manned and automatic weather station observations .....	128
d. Surface mass balance .....	129
e. 2008–2009 Seasonal melt extent and duration .....	131
f. Sea ice extent and concentration .....	131
g. Ozone depletion .....	133
<b>7. REGIONAL CLIMATES .....</b>	<b>135</b>
a. Introduction .....	135
b. North America .....	135
1. Canada .....	135
2. United States .....	137
3. Mexico .....	142
c. Central America and the Caribbean .....	143
1. Central America .....	143
2. The Caribbean .....	144
d. South America .....	146
1. Northern South America and the tropical Andes .....	146
2. Tropical South America east of the Andes .....	148
3. Southern South America .....	150
e. Africa .....	152
1. Northern Africa .....	152
2. Western Africa .....	154
3. Eastern Africa .....	154
4. Southern Africa .....	156
5. Western Indian Ocean countries .....	158
f. Europe .....	160
1. Overview .....	160
2. Central and Western Europe .....	162
3. The Nordic and Baltic Countries .....	164
4. Iberia .....	166
5. Mediterranean, Italian, and Balkan Peninsulas .....	167
6. Eastern Europe .....	168
7. Middle East .....	169
g. Asia .....	170
1. Russia .....	170
2. East Asia .....	174
3. South Asia .....	176
4. Southwest Asia .....	179
h. Oceania .....	180
1. Australia .....	180
2. New Zealand .....	184
3. Southwest Pacific .....	185
4. Northwest Pacific .....	188
<b>8. SEASONAL SUMMARIES .....</b>	<b>191</b>
Acknowledgments .....	195
Appendix: Acronyms .....	196
References .....	200



The year was characterized by a transition from a waning La Niña to a strengthening El Niño, which first developed in June. By December, SSTs were more than 2.0°C above average over large parts of the central and eastern equatorial Pacific. Eastward surface current anomalies, associated with the El Niño, were strong across the equatorial Pacific, reaching values similar to the 2002 El Niño during November and December 2009. The transition from La Niña to El Niño strongly influenced anomalies in many climate conditions, ranging from reduced Atlantic basin hurricane activity to large scale surface and tropospheric warmth.

Global average surface and lower-troposphere temperatures during the last three decades have been progressively warmer than all earlier decades, and the 2000s (2000–09) was the warmest decade in the instrumental record. This warming has been particularly apparent in the mid- and high-latitude regions of the Northern Hemisphere and includes decadal records in New Zealand, Australia, Canada, Europe, and the Arctic. The stratosphere continued a long cooling trend, except in the Arctic.

Atmospheric greenhouse gas concentrations continued to rise, with CO<sub>2</sub> increasing at a rate above the 1978 to 2008 average. The global ocean CO<sub>2</sub> uptake flux for 2008, the most recent year for which analyzed data are available, is estimated to have been 1.23 Pg C yr<sup>-1</sup>, which is 0.25 Pg C yr<sup>-1</sup> smaller than the long-term average and the lowest estimated ocean uptake in the last 27 years. At the same time, the total global ocean inventory of anthropogenic carbon stored in the ocean interior as of 2008 suggests an uptake and storage of anthropogenic CO<sub>2</sub> at rates of 2.0 and 2.3 ± 0.6 Pg C yr<sup>-1</sup> for the decades of the 1990s and 2000s, respectively. Total-column ozone concentrations are still well below pre-1980 levels but have seen a recent reduction in the rate of decline while upper-stratospheric ozone showed continued signs of ongoing slow recovery in 2009. Ozone-depleting gas concentrations continued to decline although some halogens such as hydrochlorofluorocarbons are increasing globally. The 2009 Antarctic ozone hole was comparable in size to recent previous ozone holes, while still much larger than those observed before 1990. Due to large interannual variability, it is unclear yet whether the ozone hole has begun a slow recovery process.

Global integrals of upper-ocean heat content for the last several years have reached values consistently higher than for all prior times in the record, demonstrating the dominant role of the oceans in the planet's energy budget.

Aside from the El Niño development in the tropical Pacific and warming in the tropical Indian Ocean, the Pacific Decadal Oscillation (PDO) transitioned to a positive phase during the fall/winter 2009. Ocean heat fluxes contributed to SST anomalies in some regions (e.g., in the North Atlantic and tropical Indian Oceans) while dampening existing SST anomalies in other regions (e.g., the tropical and extratropical Pacific). The downward trend in global chlorophyll observed since 1999 continued through 2009, with current chlorophyll stocks in the central stratified oceans now approaching record lows since 1997.

Extreme warmth was experienced across large areas of South America, southern Asia, Australia, and New Zealand. Australia had its second warmest year on record. India experienced its warmest year on record; Alaska had its second warmest July on record, behind 2004; and New Zealand had its warmest August since records began 155 years ago. Severe cold snaps were reported in the UK, China, and the Russian Federation. Drought affected large parts of southern North America, the Caribbean, South America, and Asia. China suffered its worst drought in five decades. India had a record dry June associated with the reduced monsoon. Heavy rainfall and floods impacted Canada, the United States, the Amazonia and southern South America, many countries along the east and west coasts of Africa, and the UK. The U.S. experienced its wettest October in 115 years and Turkey received its heaviest rainfall over a 48-hr period in 80 years.

Sea level variations during 2009 were strongly affected by the transition from La Niña to El Niño conditions, especially in the tropical Indo-Pacific. Globally, variations about the long-term trend also appear to have been influenced by ENSO, with a slight reduction in global mean sea level during the 2007/08 La Niña event and a return to the long-term trend, and perhaps slightly higher values, during the latter part of 2009 and the current El Niño event. Unusually low Florida Current transports were observed in May and June and were linked to high sea level and coastal flooding along the east coast of the United States in the summer. Sea level significantly decreased along the Siberian coast through a combination of wind, ocean circulation, and steric effects. Cloud and moisture increased in the tropical Pacific. The surface of the western equatorial Pacific freshened considerably from 2008 to 2009, at least partially owing to anomalous eastward advection of fresh surface water along the equator during this latest El Niño. Outside the more variable tropics, the surface salinity anomalies associated with evaporation and

precipitation areas persisted, consistent with an enhanced hydrological cycle.

Global tropical cyclone (TC) activity was the lowest since 2005, with six of the seven main hurricane basins (the exception is the Eastern North Pacific) experiencing near-normal or somewhat below-normal TC activity. Despite the relatively mild year for overall hurricane activity, several storms were particularly noteworthy: Typhoon Morakot was the deadliest typhoon on record to hit Taiwan; Cyclone Hamish was the most intense cyclone off Queensland since 1918; and the state of Hawaii experienced its first TC since 1992.

The summer minimum ice extent in the Arctic was the third-lowest recorded since 1979. The 2008/09 boreal snow cover season marked a continuation of relatively shorter snow seasons, due primarily to an early disappearance of snow cover in spring. Preliminary data indicate a high probability that 2009 will be the 19th consecutive year that glaciers have lost mass. Below normal precipitation led the 34 widest marine terminating glaciers in Greenland to lose 101 km<sup>2</sup> ice area in 2009, within an annual loss rate

of 106 km<sup>2</sup> over the past decade. Observations show a general increase in permafrost temperatures during the last several decades in Alaska, northwest Canada, Siberia, and Northern Europe. Changes in the timing of tundra green-up and senescence are also occurring, with earlier green-up in the High Arctic and a shift to a longer green season in fall in the Low Arctic.

The Antarctic Peninsula continues to warm at a rate five times larger than the global mean warming. Associated with the regional warming, there was significant ice loss along the Antarctic Peninsula in the last decade. Antarctic sea ice extent was near normal to modestly above normal for the majority of 2009, with marked regional contrasts within the record. The 2008/09 Antarctic-wide austral summer snowmelt was the lowest in the 30-year history.

This 20th annual *State of the Climate* report highlights the climate conditions that characterized 2009, including notable extreme events. In total, 37 Essential Climate Variables are reported to more completely characterize the *State of the Climate* in 2009.